Canadian Centre for
Occupational Health
and Safety

Centre canadien
d'hygiène et de
sécurité au travail

Emissions from Video Display Terminals and their Measurement

A Training Manual

P86-19E

87-02787/

Canadian Centre
for Occupational Health
and Safety

Emissions from Video Display Terminals and their Measurement

A Training Manual

by
- Karel Marha
- Bhawani Pathak
- David Charron

Canadian Centre
for Occupational Health
and Safety

EMISSIONS FROM VIDEO DISPLAY TERMINALS AND THEIR MEASUREMENT

A TRAINING MANUAL

CCOHS NUMBER P86-19E

ISBN 0-660-11959-5

DSS CATALOGUE NUMBER CC273-2/86-19E

This publication is available
in both official languages.

Cette publication est disponible
dans les deux langues officielles.

While the Centre endeavours to ensure the accuracy and completeness of information provided, it is understood that the Centre makes no warranty as to the accuracy or completeness of such information and assumes no liability for any damages or loss suffered as a result of any inaccuracy or incompleteness therein.

Published 1986

Additional copies available upon request.

250 Main Street East
Hamilton, Ontario
L8N 1H6
(416) 572-2981
Telex 061-8532

Canadian Centre
for Occupational Health
and Safety

CONTENTS

SECTION	CONTENT	PAGE
1	**Preface**	1
2	**Scope**	1
3	**Introduction**	1
4	**Physical structure of VDTs**	2
4.1	System organization	2
4.2	Components	3
5	**Physical characteristics of emissions from VDTs**	3
5.1	Radiation	4
5.2	Electric, magnetic and electromagnetic Fields	4
5.3	Nonionizing and ionizing radiations	6
5.4	VDT operating principle	7
6	**Emissions from VDTs and possible biological effects**	11
6.1	Electrostatic field	11
6.1.1	Field levels	11
6.1.2	Biological effects	12
6.2	Nonionizing electromagnetic radiation	12
6.2.1	Quantification of the EM field	13
6.2.2	Biological effects	13
6.2.3	Exposure limits	14
6.3	UV, visible and IR radiations	14
6.3.1	UV radiation	16
6.3.2	Exposure limits	18
6.3.3	Visible light	19
6.3.4	IR radiation	21
6.4	X-rays	21

Canadian Centre
for Occupational Health
and Safety

Contents
continued

SECTION	CONTENT	PAGE
6.4.1	Biological effects	22
6.4.2	Exposure limits	23
6.4.3	X-rays and VDTs	23
6.5	Sound and ultrasound	25
7	**Survey instrumentation and methodology**	**26**
7.1	Measurement of electrostatic field	26
7.2	Measurement of ELF and VLF magnetic fields	27
7.3	Measurement of VLF electric field	28
7.4	UV, visible and IR measurements	29
7.5	X-ray measurement	31
7.6	Ultrasound measurement	31
8	**Presentation of results and reports**	**32**
8.1	Interpretation	32
8.2	Comparison with other studies	32
8.3	Comparison with standards	32
8.4	Making recommendations	33
9	**Glossary**	**34**

1. Preface

This manual is intended to give a basic understanding of the structure of a typical VDT, possible sources of ionizing and nonionizing radiation emissions, and their possible implications on the operator's health. From the manual the user should be able to develop an understanding of how these emissions can be measured and how to interpret the results. For persons with no prior experience, this manual should be an accompaniment for training sessions. For readers with basic knowledge on the subject, it may be used as a self-study resource book.

2. Scope

This manual is designed for use as guidelines in training sessions for workers, hygienists and supervisors under the direction of a specialist in health physics. Prior knowledge of the principles of the operation of VDT components or health physics is not essential.

The training sessions and this manual will aid in developing familiarity with the VDT by providing information on the following:

1. Physical construction and the operating principles of VDTs
2. Sources of emissions, expected levels and spectral characteristics
3. Basic information about the possible or known biological effects
4. Recommended exposure limits for the various types of emissions, and comparison with some recent measurements of VDT emissions
5. Techniques and instrumentation used for field measurements

The measurement skills and supplementary information details are to be developed during laboratory sessions and group discussions at CCOHS.

3. Introduction

Video Display Terminals (VDTs) also called Video (or Visual) Display Units (VDUs) are the most commonly used means of accessing a computer. Widespread use of computers has been immensely facilitated by the invention of VDTs, eliminating the use of cumbersome and noisy punch-card-reading machines. As VDTs monitor input and output messages, consumption of paper and waiting time have been significantly reduced. Today, VDTs are used as tools for information retrieval, data processing and process control in all sectors of business, industry and research. The Ontario Public Service Employees' Union reported that there were 250,000 VDTs in use in Canada in 1981. The number of

Introduction
continued

users has been rapidly increasing in recent years, resulting in the creation of many jobs which demand routine, continuous use of VDTs for the entire work shift.

As VDT usage has grown, so too have the concerns regarding the possible health effects of such routine operation of these units. These health concerns include fatigue, eye strain, muscular strain, skin problems, birth defects and miscarriages (called here abnormal reproductive outcome). No firm scientific evidence, however, is yet available to demonstrate a proven association between VDT operation and reproductive problems. Because of the difficulties in determining the rate of abnormal reproduction outcomes in VDT operators as compared to the general population, epidemiological studies have not been able to establish that work with VDTs poses an increased reproductive risk.

Complaints of increased fatigue, eye strain, and musculoskeletal disorders, while not conclusively established, would seem to be reasonably associated with inadequate workstation and environment design and work practices (for example, job design).

While there seems to be general agreement that commonly reported disorders might well be associated with poor job design and inadequate ergonomic design of the VDT workplace, there is less agreement on the level of concern regarding emissions from these terminals.

Some specialists believe that the emissions should be viewed with some concern, while others believe that since the emissions are far below the recommended limits (although in some cases, there are no recommended limits) there should be no cause for concern. In recent years low frequency and electrostatic fields around VDTs have been shown to be substantially above background levels. The health consequences of exposure to such fields remains poorly understood.

The answers to questions about the safety of VDT emissions can come only from carefully planned scientific research. Given the present state of knowledge, emission levels from the equipment should be kept as low as practically possible, and the design of the workstation and the job design should be optimized for the comfort of the operator.

4. Physical structure of VDTs

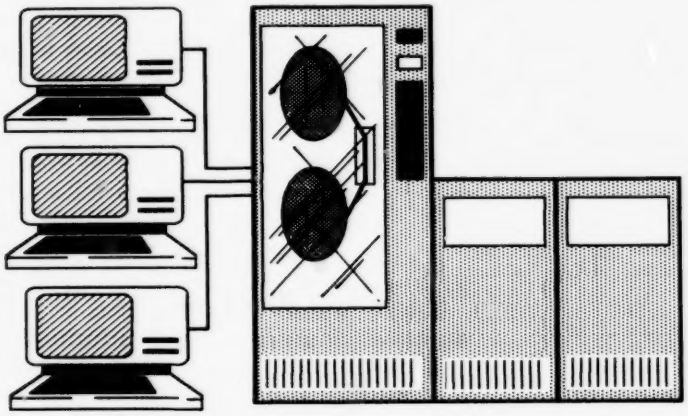
4.1 System organization

The role of the VDT in a computer system is explained in Figure 1. Data, programs, text and search information or other input are sent to the computer by the operator through the VDT. After processing of this information by the computer, the result is displayed on the screen of the VDT, part of the cathode ray tube (CRT).

4.2 Components

A VDT has two basic parts, a keyboard and a visual display which contains the CRT. In older models the keyboard is attached to the display unit. In newer ones, the keyboard is detachable so that it can be optimally positioned by the operator. The keyboard itself is similar to that of a typewriter. In addition to letters, numbers and punctuation marks there are keys which send instructions for special computer functions. Text typed on the keyboard is sent to the computer for processing and display on the screen of the VDT. From the radiation point of view the keyboard is harmless.

Figure 1 Computer access through a VDT



The operating principles of the VDT are exactly the same as those of a household television (TV) set. The only difference is that the household television receives electrical signals through the TV antenna or cable, while the VDT receives signals from the keyboard and the computer.

5. Physical characteristics of emissions from VDTs

Because of its physical structure and mode of operation, a VDT is potentially capable of producing the following types of emissions:

1. X-rays (ionizing radiation)
2. Electrostatic field
3. Extremely low and very low frequency electric and magnetic field
4. Infrared (heat) rays, visible light, ultraviolet rays
5. Ultrasound
6. Noise
7. Fumes and vapours

Emissions under item 1. are called ionizing radiation while emissions under 2. to 6. are called nonionizing radiation.

5.1 Radiation

Radiation is the process of emitting energy in the form of particles or waves. In the case of VDTs we have to take into account only radiation in the form of electromagnetic waves. (Items 1-4 in the above list.)

Electromagnetic waves include both ionizing and nonionizing radiation, the classification being made on the basis of energy associated with the smallest quantum of radiation called a photon. For more details see Section 5.3.

5.2 Electric, magnetic and electromagnetic fields

An electrically charged body creates an electric field around it. If the charge does not change polarity from time to time it generates an electrostatic, or stationary, field in its vicinity.

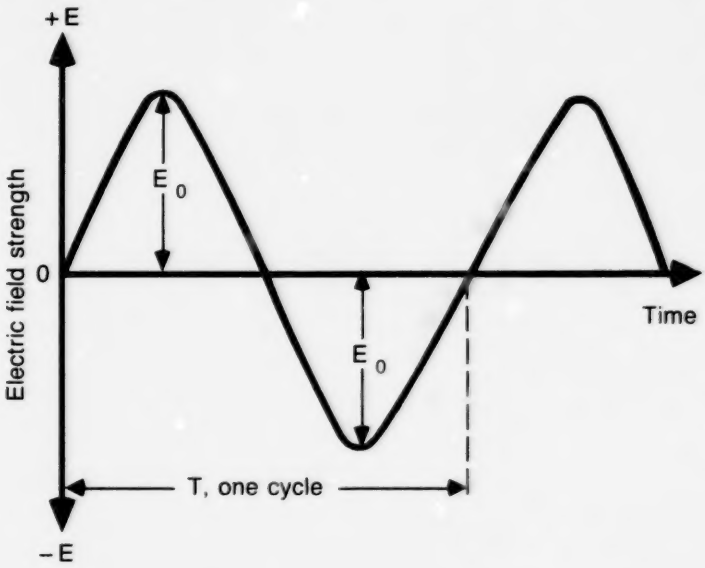
If there is a difference in the magnitude of electric charge between two sides of a conductive material, an electric current flows through the conductor. This electric current generates a magnetic field around the conductor. Current which always flows in one direction is said to be direct current (DC). DC produces a steady magnetic field around the wire.

When the sign of the electric charges change repeatedly over time, the direction of current flow is periodically reversed, accordingly. This effect is called an alternating current (AC), which produces electric and magnetic fields. These two fields combine to create the electromagnetic (EM) field which travels away from the source at the speed of light (3×10^8 meters per second) in free space. Like any other wave motion the EM waves are characterized by their frequency and intensity.

Electric magnetic and electromagnetic fields *continued*

Frequency is the number of cycles or waves transmitted by the radiating system per second (see Fig. 2). The intensity of radiation (that is, intensity of the field or field strength) depends on the passing through a unit area per second and depends on the amplitude E_0 in Fig. 2.

Figure 2 Simplified view of alternating current field



E_0 = amplitude (peak value of field)
T = period, or time in sec for one cycle

$\frac{1}{T} = f$ = frequency (Hz)

The properties of the electromagnetic wave are dependent on their frequency. Therefore, the type of interaction with biological matter strongly depends on the frequency of the radiation. The magnitude of the biological effect depends primarily on the frequency and field strength.

The unit of frequency is called hertz (Hz) meaning one cycle per second. Prefixes are commonly used to designate higher frequencies. One thousand hertz is one kilohertz (kHz), one million hertz is one megahertz (MHz) and one thousand megahertz is one gigahertz (GHz). These higher frequencies can be expressed by use of the exponent (base of 10). For example, one kilohertz equals 10^3 Hz, one megahertz is 10^6 Hz and one gigahertz is 10^9 Hz.

Electric, magnetic and electromagnetic fields *continued*

Another term often used to characterize EM waves is wavelength. The wavelength is inversely proportional to the frequency and can be calculated by the following:

wavelength = speed in given environment/frequency

For example, the EM waves from a microwave oven have a frequency of 2450 MHz (megahertz) and therefore the corresponding wavelength in air is 12.2 centimeters. In comparison, the 60 Hz electric field from overhead powerlines has a wavelength of 5000 kilometers. Frequency ranges of EM waves are assigned designations as shown in Table 1.

Table 1 Radiofrequency bands and their uses

Frequency	Wavelength	Band Designation	Typical Uses
300-3000 GHz	1-0.1 mm	Supra EHF (extremely high frequency)	Not allocated
30-300 GHz	10-1 mm	Extremely high frequency (EHF)	Satellite communications, radar
3-30 GHz	10-1 cm	Super high frequency (SHF)	Satellite communications, radar
0.3-3 GHz	100-10 cm	Ultra high frequency (UHF)	UHF-TV, microwave ovens, ISM
30-300 MHz	10-1 m	Very high frequency (VHF)	VHF-TV, industrial RF equipment diathermy.
3-30 MHz	100-10 m	High frequency (HF)	Medical diathermy, industrial RF equipment
0.3-3 MHz	10^3-10^2 m	Medium frequency (MF)	Industrial RF equipment, AM broadcast
30-300 kHz	10-1 km	Low frequency (LF)	Radionavigation, long-range communications
3-30 kHz	100-10 km	Very low frequency (VLF)	Very long range communications.
30 Hz-3 kHz	10^4-10^2 km	Extremely low frequency (ELF)	Powerlines
0-30 Hz	10^4 km	Sub-ELF	DC powerlines

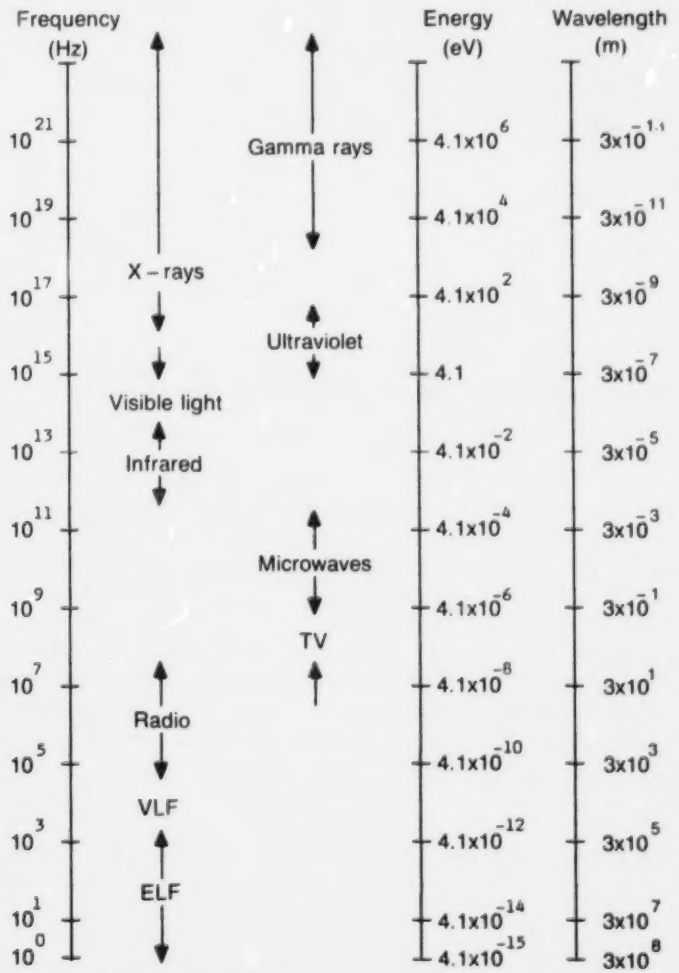
Source: Taken from Biological Effects of Radiofrequency Radiation, EPA publication EPA-600/8-83 September 1984.

5.3 Nonionizing and ionizing radiations

Nonionizing radiation includes electric and magnetic fields from DC (zero Hz frequency) through radiofrequency (RF) and microwave radiations to infrared rays (thermal radiation), visible light and ultraviolet rays (Fig. 3). These types of radiation are termed nonionizing because their photons are not sufficiently energetic to produce ions by stripping off electrons from atoms as they pass through a material. Ionizing radiation, as the name suggests, does produce ions by this process. While ionizing radiation loses energy by the formation of ions, nonionizing radiation generates heat as it passes through material. Some non-thermal mechanisms of interaction are also known.

Ultrasound, which is sound with frequency above the range detectable by the human ear (approximately 16 kHz and higher, dependent on age), is often included in the category of nonionizing radiation.

Figure 3 Electromagnetic spectrum

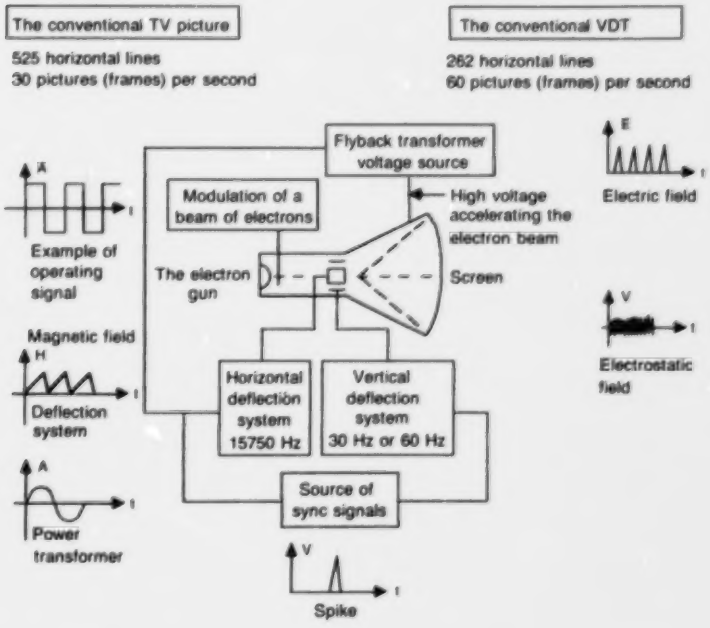


5.4 VDT operating principles

The heart of the VDT is the cathode ray tube (CRT) and the associated electronic controls. A diagram is shown in Figure 4. The CRT is an evacuated glass tube containing an electron gun. Together with the focusing system, they produce a narrow beam of electrons. The electron beam is accelerated towards the front of the tube by a positive high voltage in the range of 10 - 25 kilovolts (kV). The generation of this high voltage will be described at the end of this chapter. For now, the general rule is that the larger the screen area, the higher the voltage required. Color VDTs need higher voltages than monochrome VDTs, size for size.

The focused, accelerated electron beam strikes the coating on the inner surface of the CRT (this coating is called phosphor) producing a bright spot. The colour of the spot depends on the characteristics of the phosphor.

Figure 4 Video display terminal - main parts



Most VDTs display images by dividing the picture into a series of lines, called raster lines. Raster lines appear on the screen as the electron beam sweeps from left to right and top to bottom (Fig. 5). One can see raster lines on a television set when there is no signal.

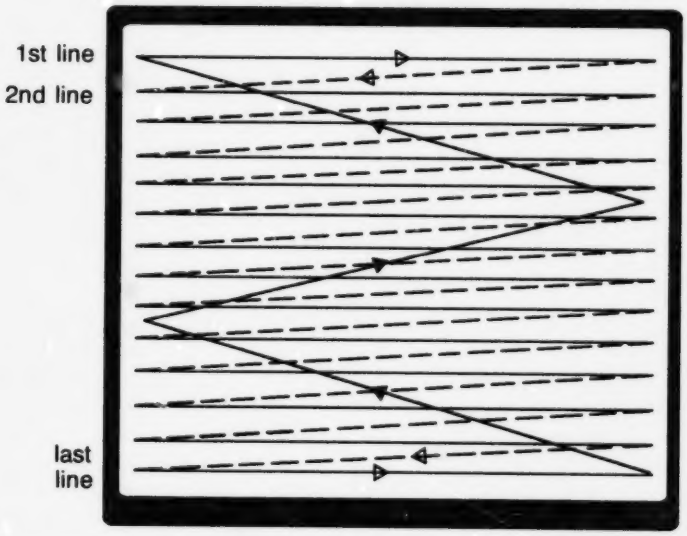
VDT operating principles *continued*

The electron beam is moved across the face of the cathode ray tube by the horizontal and vertical deflection system. This system consists of coils wound in a yoke, which are placed over the neck of the cathode ray tube. These coils behave like magnets when an electric current flows through them. Magnetic fields deflect electrons, so, by adjustment of the currents in the coils, the electron beam can be moved from side to side, up or down, or in any direction.

There are two sets of coils, one moving the electron beam from left to right; the other, from top to bottom.

Figure 5

Raster lines-dashed lines are invisible retrace lines

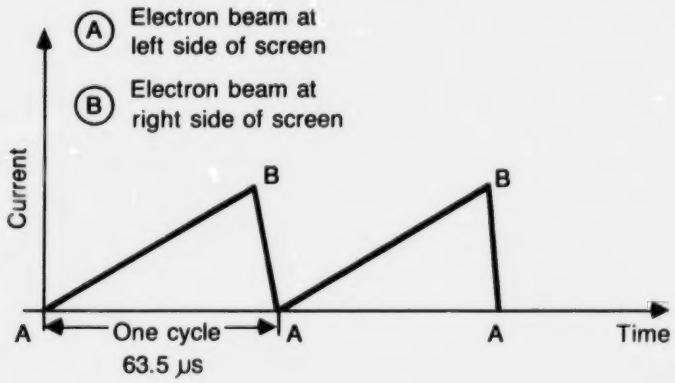


Every time the electron beam reaches the right-hand side of the screen, a special signal, called the horizontal synchronization (sync) pulse, causes a rapid falling of the current through the horizontal deflection coil. As a result the electron beam rapidly moves back to the left side of the screen. In other words (see Fig. 6), the current in the horizontal deflection coil increases in a linear ramp-like fashion, making the electron beam move horizontally from left to right, so producing the raster scan line. Then the current quickly returns to the lowest level, the electron beam returns to the left side of the screen and the current starts to increase again through the coil. This cycle is repeated according to the number of lines in the picture.

Most VDTs produce 262 raster lines per picture (also called frame) and 60 frames per second.

Figure 6

Time-change of the current in the horizontal deflection coil



As shown in Fig. 5, while the electron beam moves from left to right across the screen, it also moves slowly from top to bottom. This vertical movement is caused by the increasing magnitude of current through the vertical deflection coils. The change in magnitude of this current in time is similar to the current waveform in the horizontal deflection coils (Fig. 6).

The time required by the electron beam to move horizontally from left to right is in the range of 54 to 64 microseconds (a microsecond is one millionth of a second) and it varies from system to system. From right to left, it takes only 6-10 microseconds (which corresponds to the horizontal sync pulse time). On the other hand, the time required by the electron beam to move from top to bottom of the screen is about 16 milliseconds (a millisecond is one thousandth of a second).

The conventional video display terminal in North America uses 60 frames or pictures per second, so the vertical scan frequency is 60 Hz. Because the beam travels back and forth approximately 262 times for every picture, the horizontal scan frequency is 15.72 kHz (60 x 262).

Some systems may use a different number of lines and frames per second and therefore the horizontal scan frequency can vary between 10 to 30 kHz and the vertical scan frequency can be as low as 30 Hz.

In order to produce an electron beam with sufficient energy to produce visible light on the face on the VDT screen, a large DC voltage is produced by sending the horizontal deflection signal through a step-up transformer. The frequency of this signal is around 16 kHz.

The transformer used for this purpose is called flyback transformer, since it produces synchronization pulses which cause the electron

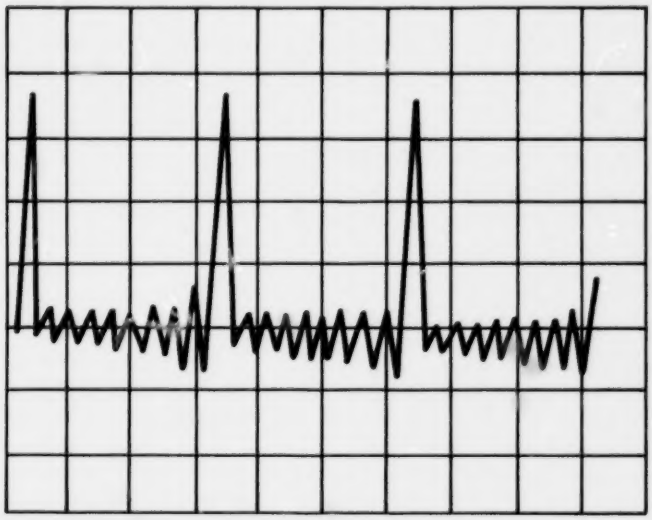
VDT operating principles *continued*

beam to quickly "flyback" from the right side of the screen to its left side. The flyback transformer simply steps up the voltage to a large value every time the electron beam reaches the right side of the screen.

The waveform of the flyback transformer output signal is illustrated in Fig. 7.

Figure 7

Waveform of 15.9 kHz pulsed field from high voltage circuit (flyback transformer)



6. Emissions from VDTs and possible biological effects

The high voltage which accelerates the electron beam causes an electrostatic charge on the CRT screen.

When the electron beam strikes the atoms of phosphor, some X-rays, and infrared and ultraviolet rays, are produced in addition to visible light.

The leakage of electromagnetic radiation from different types of video display terminals varies from model to model. Four types of fields have been found to be at levels substantially above background levels. All of these are in the lowest part of the electromagnetic spectrum. By frequency, they are the DC (direct current) electrostatic field (from the charged screen), the extremely low frequency (ELF) magnetic field and the very low frequency (VLF) magnetic and electric fields generated by the deflection coils and flyback transformer.

The electronic circuitry controlling the computer and terminal operation generates some very weak electromagnetic emissions in a broad frequency range up to 30 MHz.

Emissions from VDTs and possible biological effects
continued

The cooling fan may generate audible noise. Sound at a basic frequency of around 16 kHz can be produced by friction of the core of the flyback transformer during minute movements induced by rapid current changes in the windings of the transformer.

6.1 Electrostatic field

The VDT screen becomes electrically charged (the screen has a DC potential) during operation because of the high voltage used to accelerate the electron beam. Under the influence of this electrostatic field, objects with a charge of the same polarity are repelled; those with opposite polarity are attracted. Uncharged objects become attracted towards charged ones.

6.1.1 Field levels

Measured potentials on the screen surface range from 0 V to +12000 V, with an average of 2250 V. The operator's body also may become charged depending on the type of clothing worn, and environmental factors such as humidity, location, pattern of movement, floor coverings, and furniture material. Measured potentials on operators were found to range from -2000 V to +4000 V. With such voltages, an electrostatic field gradient (or difference) develops between the operator and the screen. The gradient of this electrostatic field is measured in volts per centimeter (V/cm). With the values of screen and operator potentials mentioned above, the percentage of operators exposed to different electrostatic field gradients was calculated (see Table 2).

Table 2 Percentage of VDT operators working in given electrostatic field gradient

Field Gradient	Operator's distance from the screen	
	30 cm	50 cm
1 - 100 V/cm	60%	81.5%
up to 200 V/cm	80%	96.5%
above 200 V/cm	20%	3.5%
above 300 V/cm	4.5%	0%
above 400 V/cm	0.75%	0%

Source: From the data in the report by W.C. Olsen, Electric Field Enhanced Aerosol Exposure in Visual Display Unit Environment. Christian Michelsons Institute, Bergen, Norway, April 1981.

6.1.2 Biological effects

Electrostatic fields may cause airborne particles to be attracted to the operator's face, which then might cause skin and eye

Biological effects *continued*

irritation. Some scientific evidence has been obtained to indicate possible links between skin rashes and work with VDTs.

Some studies suggest that the health complaints of VDT operators may be linked to the distortion of the ionic environment by the electrostatic field in front of the VDT. The positive charge on the VDT screen may result in a depletion of negative ions in the air around the operator. Higher positive ion concentrations are reported to cause psychological distress, fatigue and behavioural changes.

The positive ions are alleged to cause changes in serotonin concentration in the brain. This mechanism could perhaps be responsible for "stress" and behavioural changes, but the whole question of effects of ions, positive or negative, is controversial.

6.2 Nonionizing electromagnetic radiations

The horizontal and vertical deflection system and the high voltage circuitry are responsible for generating magnetic and electric fields in the extremely low (30-60 Hz) and very low (15-30 kHz) frequency ranges. All of these are pulsed fields with intensities (in some places around VDTs) much higher than background levels.

The radiated power is proportional to the product of the magnitudes of electric and magnetic fields, and represents a flow of energy in the direction of propagation. The rate at which the energy flows through a unit area in space is called the power density. At distances of greater than a few wavelengths from a source only one of the components of the electromagnetic field (electric or magnetic) needs to be measured; the two others (electric or magnetic field and power density) may be calculated.

In this so-called "far-field" region, the inverse square law applies, meaning that the power density decreases with the square of the distance from the source. If the distance from the source is doubled the power density will be reduced by a factor of four.

The region very close to the source of electromagnetic radiation (within a few wavelengths) is known as the "near-field". In the near-field region none of those far-field calculations are valid. *Since measurements on VDTs are well within the near-field (wavelength of the 16 kHz field is approximately 19 km), it is necessary to measure both electric and magnetic fields separately.*

6.2.1
Quantification of the EM field

The exposure of a worker to a source of EM radiation is measured by power density, and the magnitude of electric and magnetic fields. Power density is defined as the energy flowing per square area per second and is measured in watts per square meter (W/m^2) or milliwatts per square centimeter (mW/cm^2). The electric field is measured in volts per meter (V/m). The magnetic field is measured in units of amperes per meter (A/m). In the far field region these three measures are related by the following equations:

Power density (W/m^2) = electric field (V/m)
x magnetic field (A/m)

or power density (mW/cm^2) = E^2(V/m)/3770
= H^2(A/m)x37.7

In the near field region, the above simple relations are not valid and, exposure is given as measures of electric field (E) and the magnetic field (H). Often an *equivalent power density* is erroneously calculated from measured near-field strengths by using field and power density relationship as used in the far-field region.

6.2.2
Biological effects

The biological effects of electromagnetic fields (radiofrequency and microwave exposure) are:

1. Thermal effects
2. Non-thermal or athermal effects

Body fluids are made up of molecules which are electrically polarized because they contain atoms whose positive and negative charges are not homogeneously distributed in the molecule. These molecules interact with the alternating electric field and absorb energy which is transformed into heat thus resulting in thermal effects. The higher the frequency and the field intensity, the more heat that is generated. The rate at which energy is absorbed in the living body is called specific absorption rate (SAR) and is expressed in watts per kilogram of body weight (W/kg).

There is no apparent thermal effect for the magnetic field. However at very high magnetic field intensities, electric currents can be induced in the body, and mainly in lower frequency ranges, mechanisms other than generation of heat are possible.

The organs most sensitive to thermal effects are the eyes and the testes because of their poor thermoregulatory capabilities. The

Biological effects *continued*

measured levels and frequencies of electromagnetic emissions from VDTs are too low to cause thermal effects.

The non-thermal effects are reported to occur at very low exposures far below those which cause any significant increases in body temperature. The health effects alleged to be linked to the exposure of low levels of EM radiation are disorders of the central and peripheral nervous systems, cardiovascular system and the hematological (blood) system. Some of the common complaints are shown in Tables 3 and 4. The mechanisms by which these non-thermal effects are produced are not clearly understood. There have been numerous attempts to verify them by laboratory experiments and epidemiological studies. The results obtained to date are not sufficient to prove, one way or the other, whether long term exposure to low level electromagnetic field causes adverse health effects.

Table 3 Clinical findings among 525 workers chronically exposed to electromagentic fields

Symptoms
1. Increased fatigue
2. Periodic or constant headaches
3. Extreme irritability
4. Sleepiness during work
5. Decrease in olfactory (smell) sensitivity
Signs
1. Bradycardia (reduced heart beat)
2. Hypotension (low blood pressure)
3. Hyperthyroidism (excessive activity of the thyroid gland)
4. Increase in blood histamine level

Source: Letavet, A.A., and Z.V. Gordon, Biological action of ultra high frequencies. U.S.S.R. Academy of Medical Science. Translation 12 471, U.S. Joint Pub. Res. Service, 1962.

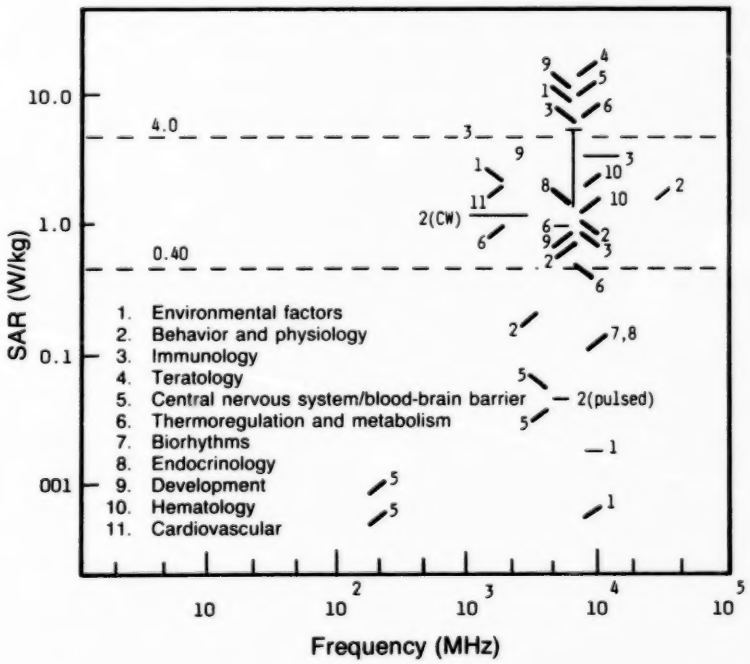
Table 4 Subjective effects on workers exposed to electromagnetic fields

Headaches	Feelings of fear
Eyestrain	Nervous tension
Fatigue	Mental depression
Dizziness	Impaired memory
Disturbed sleep	Pulling sensation in scalp
Sleepiness during daytime	and brow
Moodiness	Pain in muscles
Irritability	Pain region of heart
Unsociability	Breathing difficulties
Hypochondriac reactions	Increased sweating of
Difficulties in sex life	extremities

Source: Marha, K.; J. Musil, and H. Tuha. Electromagnetic Fields and the Life Environment. San Francisco Press, San Francisco, 1971

Animal experiments have demonstrated that pulsed EM radiation could be more effective in causing biological effects than continuous wave (cw) radiation. (See Fig. 8, points marked 2).

Figure 8 Whole-body averaged specific absorption rate (SAR)*



*Corresponding to effects reported in literature used as basis for the 1982 ANSI C95.1 standard.

Source: R.C. Patterson, Journal of Occupational Medicine Vol. 25, 1983. p. 103

6.2.3 Exposure limits

In North America, the exposure limits for microwave and radiofrequency radiation are based on protection against thermal effects. As a base an SAR equal to 0.4 W/kg of body mass was chosen (see Fig. 8). In Canada, the recommended exposure limits are given in the Health and Welfare Canada publication Safety Code - 6. These limits are summarized in Table 5.

Recommended exposure limits covering frequency regions below 10 MHz are compiled in Table 6.

Table 5 Safety code - 6 exposure limits

Exposure Catagory	Frequency Range	Measured EM field Parameter*	Exposure limit averaged over 1 hour	1 minute
Occupational whole or partial body	10 MHz-1 GHz	E	60 V/m	300 V/m
		H	0.16 A/m	0.8 A/m
		P	1 mW/cm^2	25 mW/cm^2
	1 GHz-300 GHz	E	140 V/m	300 V/m
		H	0.36 A/m	0.8 A/m
		P	5 mW/cm^2	25 mW/cm^2
Extremities	10 MHz-300 GHz	E	200 V/m	300 V/m
		H	0.5 A/m	0.8 A/m
		P	10 mW/cm^2	25 mW/cm^2
Non Occupational: General Public	10 MHz-300 GHz	E		60 V/m
		H		0.16 A/m
		P		1 mW/cm^2

* E = Electric field H = Magnetic field P = Power density

Table 6 Some standards covering the very low frequency and the low frequency range

	Frequency	Electric Field	Magnetic Field
US Air Force	10 kHz - 10 MHz	435 V/m	
ACGIH	10 kHz - 3 MHz	614 V/m (2)	1.6 A/m
Czechoslovakia	30 kHz - 30 MHz	50 V/m (1)	
USSR	30 kHz - 300 kHz	50 V/m (5)	
	300 kHz - 3 MHz	15 V/m (5)	
Bulgaria	60 kHz - 3 MHz	50 V/m (1)	
GDR	60 kHz - 3 MHz	50 V/m (1)	
Canada (Ontario)	300 kHz - 300 GHz	60 V/m (3)	0.16 A/m
ANSI (C95.1-1982)	300 kHz - 3 MHz	632 V/m (2)	1.6 A/m
IRPA	100 kHz - 1 MHz	194 V/m (1)	0.51 A/m
German Federal Rep.	10 kHz - 30 kHz	1500 V/m (1)	350 A/m
	30 kHz - 2 MHz	1500 V/m (1)	7.5/f A/m (4)

1. Standards in the workplace. The values for the general public are often even more stringent (e.g. in Czechoslovakia 5 V/m for 24 hours corresponding to 15 V/m for 8 hours).
2. At a distance of 5 cm from any point on the surface of the device.

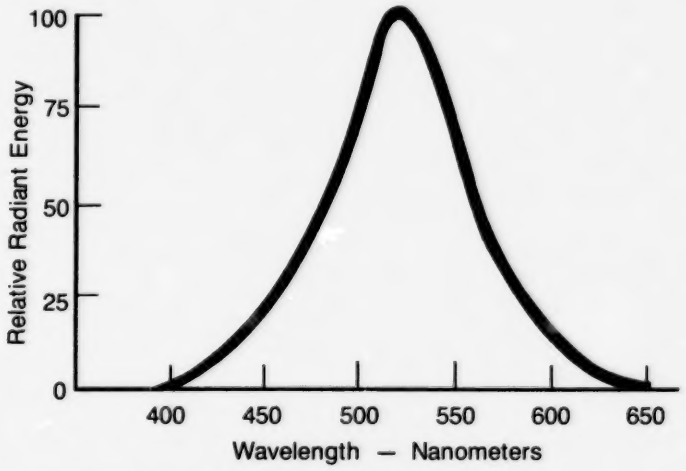
3. "For discussion only" guideline.
4. f is the frequency in MHz
5. General population

ANSI American Standards Institute (approved as an American National Standard on July 30, 1982)
ACGIH American Conference of Governmental Industrial Hygienists
IRPA International Radiation Protection Association
GDR German Democratic Republic

6.3 UV, visible and IR radiations

The electron beam interacts with the phosphor coating inside the cathode ray tube generating a spot of visible light. The colour of the spot depends on the phosphor's composition. Fig. 9 shows the spectral distribution of one commonly used phosphor (P42). Some phosphors generate a small portion of ultraviolet (UV) and/or infrared (IR) radiation in addition to visible light.

Figure 9 Energy distribution curve for CRT using P42 phosphor



Source: Human factors of workstations with display terminals; IBM publication G320-6102-1, 1979, second edition.

6.3.1 UV radiation

Ultraviolet radiation is the part of the electromagnetic spectrum between visible light and the weakest ionizing radiation (soft X-rays). The wavelength of UV radiation is between 100 nm to 400 nm (nanometer, one billionth of a meter).

The most biologically active region is between 240 and 300 nm. The main effects are skin and eye disorders. The severity of ultraviolet injury depends on exposure time, intensity of radiation, wavelength of radiation, individual susceptibility and the presence of sensitizing agents (e.g. some drugs).

UV radiation *continued*

The most common effect of UV on the skin is sunburn. Long-term low-level exposures to UV may ultimately cause skin cancer in some people. The eye disorders caused by UV exposure are conjunctivitis (inflamation of the conjunctiva) and photokeratitis (light-induced inflamation of the cornea).

6.3.2 Exposure limits

In recognition of the wavelength dependance of the potential for causing skin and eye damage, ACGIH (The American Conference of Governmental Industrial Hygienists) has developed a wavelength dependent set of exposure guidelines. Most jurisdictions in Canada have adopted these guidelines for setting occupational exposure limits. The ACGIH exposure guidelines for UV radiation are shown in Table 7.

Table 7 Threshold limit values (TLV) and relative spectral effectiveness by wavelength for 8-hour period of exposure

Wavelength, (nm)	TLV J/m^2*	Relative spectral effectiveness
200	1000	0.03
210	400	0.075
220	250	0.12
230	160	0.19
240	100	0.30
250	70	0.43
254	60	0.50
260	46	0.65
270	30	1.00
280	34	0.88
290	47	0.64
300	100	0.30
305	500	0.06
310	2000	0.015
315	10000	0.003

*J/m^2 = joules/square meter

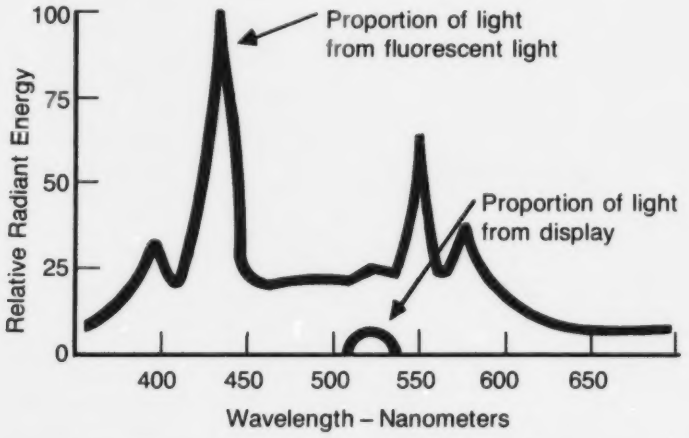
The field measurements of UV radiation around VDTs reveal that the levels are not detectable above background level because all generated UV (if any) is absorbed in the glass of the CRT screen.

6.3.3 Visible light

The visible light at the VDT workstation is made up of contributions from general room lighting, manuscript lighting and the visible light emitted by the screen. Of these, the light produced by the screen makes only a very minor contribution to the total light. (Figure 10).

Figure 10

Contribution of the light from VDT to the total light at the operator's workplace



Source: Human factors of workstations with display terminals; IBM publication G320-6102-1, 1979, second edition.

The visible light problems associated with VDTs involve the following:

1. inadequate or inappropriate room lighting level and position
2. glare
3. flicker

Inadequate room lighting causes eye fatigue, headaches, irritability, eye pain and strain in the iris and eye muscles. Retinal damage is possible only from exposure to very intense sources such as lasers. Neither room lighting nor emissions from the VDT screen could cause retinal damage. The recommended lighting level for VDT areas is in the range of 300-500 lux.

Glare may be caused by poorly placed light fixtures, windows, too much light and reflections from the VDT screen, walls and the furnishings. Much of the problem can be avoided by choosing an adequate room lighting system and appropriate finishes on walls and furniture.

The flicker is associated with the refresh rate of the image on the screen (number of pictures per second) and decay rate of the brightness of the phosphor. Flicker causes visual fatigue and psychological distress. Under normal operating conditions the flicker from the VDT should not be noticeable.

Adequate lighting of the VDT work station is beyond the scope of this manual. The literature on ergonomic factors of work station design should be consulted. (for example, National Institute of

Visible light *continued*

Occupational Health and Safety Research Report NIOSH No 81-129).

6.3.4 Infrared radiations

The region of electromagnetic spectrum between microwaves and visible light is known as infrared (IR). The IR region includes wavelengths from 0.78 to 1000 um (micrometer, one millionth of a meter).

Infrared radiation is essentially heat. Its presence is readily felt by the worker in the form of a sensation of warmth on exposed parts of the body. Excessive exposure may lead to burns (not a possibility with VDT use). The lens of the eye is the most vulnerable organ for IR exposure because the lens has poor thermoregulatory capabilities. Chronic exposure may result in cataract formation (a clouding of the lens of the eye).

No cases of excessive exposure to IR radiation have been reported among VDT operators. Though IR radiation is not a problem, the operation of a VDT does produce some heat (equal approximately to 70 W electrical heater) but in a well-ventilated and air-conditioned room this heat is quickly dissipated.

6.4 X-rays (ionizing radiation)

When the energetic (10-25 kilovolts) electron beam strikes the phospor coated glass screen, weak X-rays are produced. Its energy spectrum depends on the composition of the phosphor.

X-rays are electromagnetic waves belonging to the ionizing radiation category. They interact with biological matter by creating positively-charged ions and electron pairs as they pass through tissue.

In the older system of units, X-ray exposure was given in roentgens (R), a measure of the ionization of air, and rad, the dose of energy absorbed per unit of tissue volume.

1 rad = 0.01 joule per kilogram of tissue (joule is a unit of energy)

The potential for causing damage is strongly dependent on the type of ionizing radiation. To take this into account the dose in rads is multiplied by a quality factor (QF). Such a product is known as an equivalent dose and is measured in rems. For X-rays the value of QF is 1 and therefore absorbed dose in rads equals the equivalent dose in rems.

X-rays (ionizing radiation) *continued*

Now, in the international system of units (SI or Système Internationale), the unit of absorbed dose is gray (Gy) and the unit of dose equivalent is sievert (Sv). The new and old system of units are related by the following equation:

1 gray (Gy) = 100 rads or 1 rad = 10 mGy
1 sievert (Sv) = 100 rems or 1 rem = 10 mSv

Long-term risks associated with exposure to low-level ionizing radiation are often correlated with the whole body dose. A method has been developed to calculate effective equivalent dose from the dose received by a particular organ by multiplying it by a weighting factor. The effective equivalent dose equals the sum of single doses to different organs multiplied by the weighting factor for each organ.

The weighting factors for different organs are given in Table 8.

Table 8 Weighting factors (W_T) and risk factors for tissues at risk of stochastic effects

Tissue	Risk, Sv^{-1}	Comments	W_T
Gonads	4.0×10^{-3}	Genetic risk to first 2 generations	0.25
Breast	2.5×10^{-3}	Average for all ages and both sexes	0.15
Red bone marrow	2.0×10^{-3}	Leukemia	0.12
Lung	2.0×10^{-3}	Cancer	0.12
Thyroid	5.0×10^{-4}	Fatal cancer	0.03
Bone surface	5.0×10^{-4}	Osteosarcoma	0.03
Remainder	5.0×10^{-3}	Cancer, assuming that no single tissue contributes more than 1/5 of this total	0.30
Total risk	1.65×10^{-2}		

Source: ICRP Publication 30

6.4.1 Biological effects

The health effects of ionizing radiation can be divided into four broad categories:

1. **Acute radiation syndrome** - These effects range from general unwellness to sudden death of the exposed person. Such exposures cannot occur as a result of VDT operation.

2. **Latent effects** - These effects, such as cancer, may occur several years after a brief and intense, or habitual and low-grade exposure to low levels of ionizing radiation and involve different types of cancer. Such effects may be observed only in a small proportion of the exposed population. Statistically,

Biological effects *continued*

this means that in the exposed population each individual has a certain degree of risk of developing cancer. The risk is believed to be proportional to the total radiation dose received.

3. **Prenatal developmental effects** - While these effects are only conclusively established for leukemia caused by prenatal X-rays, available evidence suggests that ionizing radiation can damage the developing human fetus. There is insufficient evidence presently available to provide a quantitative estimate of the risk associated with fetal exposure to ionizing radiation. These effects are unlikely to occur in VDT operations.

4. **Genetic effects** - Animal experiments have shown that exposure to ionizing radiation can cause damage or alteration of chromosomes which contain the elementary unit of heredity. Very limited information is available from observations of the effects of human exposure. It is estimated that if a million people each receive a whole-body dose of 1 mSv, 4 genetic defects may develop amongst their children and grandchildren. Again, these effects are unlikely to occur in VDT operators.

6.4.2
Exposure limits

According to the recommendations of the International Commission on Radiological Protection (ICRP) the annual *occupational* dose must be kept below the following levels:

1. 50 mSv (5 rem) effective dose equivalent
2. 150 mSv (15 rem) for the lens of the eye

The recommended annual dose limit for the *general public* has been set at one-tenth of the occupational exposure limit.

6.4.3
X-rays and VDTs

Some of the earliest concerns about the potential hazards of VDT operation were linked to the ionizing radiation exposure. These concerns have led to a number of studies which report measurement of X-ray emissions from VDTs. With only a few exceptions, the X-ray levels were either not detectable or were far below the recommended permissible exposure limits. These observations demonstrate that all the X-rays produced inside the CRT are absorbed by the glass enclosure. In Table 9 some of the recent results are summarized.

Table 9 Measured X-ray emissions from VDT screen at different distances

Reference	Measure X-ray level in front of screen at distance 1 cm	5 cm	10 cm
NRPB (1983)+	-	ND	ND
McGill (1984)	-	ND	-
Ontario Hydro (1983)	ND	-	-
Paulson et al (1984)	-	3 μR/h	-
Cox, Executive, UK (1980)	10 urem/h	-	-
NIOSH (1981)	ND	-	-
IAEA (1979)	ND	-	-
U.S. Bureau of Radiological Health (1981)		ND++	

Notes: 1. Normal background radiation is approximately 10 μR/h

2. The maximum permissible annual radiation exposure for the general population is 5 mSv or 0.5 rem. This would mean that for VDT operators the exposure rate should be below 0.25 mrem/hour when working 40 hours per week and 50 weeks a year.

3. ND = not detectable

\+ National Radiation Protection Bureau Canada.

++ Out of 125 VDTs measured, 10 showed measurable levels of X-rays ranging from 0.4 - 2.0 mR/h. The noncompliant VDTs were either recalled or modified to meet the standards. Some emitted X-rays for a few minutes and then became nonoperational because of electronic failure. Under the worst operating condition of 2.0 mR/h emission, the annual dose would be 4 rems (assuming 2000 working hours per year and 1 rem dose corresponding to 1 roentgen exposure). This annual dose exceeds the population exposure limits but is below the limit of 5 rems/year recommended for radiation workers.

It may be inferred that, since under normal operating conditions there is no possibility of ionizing radiation exposure of VDT operators, reported health disorders may not be attributable to ionizing radiation. But the cause of concern may not be absolutely ruled out because exposures amounting to levels well above the recommended dose for the general public are possible from malfunctioning older types of VDTs, using vacuum tubes in the high voltage stage.

X-rays and VDTs *continued*

Around normally functioning VDTs, manufactured in the last decade, no X-ray emission has been found to be detectable above background radiation levels (approximately 100 mrem/year). Therefore, carcinogenic, developmental or genetic effects due to X-rays from VDT operation seem highly improbable.

6.5 Sound and ultrasound

In a VDT, the only moving parts capable of producing noise are the cooling fan and flyback transformer. Normally, the sound from the fan is not audible even in a quiet office environment and poses no health problems.

The mechanical response of the flyback transformer to high voltage sweep peaks (15 - 32 kHz) produces ultrasound. The acoustic energy emitted from the VDT may be further modified by the resonance and absorption properties of the VDT enclosure.

In air, ultrasound, like other forms of sound, is propagated as mechanical waves. The only difference is that the ultrasound frequencies are above the audible frequency range (16 kHz is the upper limit for most people).

The subjective effects of airborne ultrasound exposure in industrial environments (in the vicinity of 20 kHz and 110 dB) are said to include fatigue, headache, tinnitus (a sensation of noise as a ringing or roaring), a 'fullness' in the ear, and nausea.

The exposure limit to upper sonic and ultrasonic radiation in Canada is 80 dB (Table 10)

Table 10 Sound pressure level within one-third octave band (dB relative to 20 uPa)

Mid-frequency of one-third octave band (kHz)	Japan (1971)	Acton (1975)	USSR (1975)	USAF (1976)	Canada (1980)	Sweden (1978)	ACGIH (1981)	IRPA draft (1981)
8	90	75			80		80	80
10	90	75			80		80	80
12.5	90	75	75	85	80		80	80
16	90	75	85	85	80		80	80
20	110	75	110	85	80	105	105	80
25	110	110	110	85	110	110	110	110
31.5	110	110	110	85	110	115	115	115
40	110	110	110	85	110	115	115	110
50	110		110		110	115	115	110

Exposure limits (dB) for airborne acoustic energy at the workplace (exposure exceeding 4h/day)

Sound and ultrasound *conitnued*

In a survey of VDTs by U.S. Bureau of Radiological Health (BRH) the ultrasound emissions from 25 VDTs of different models were measured. The highest pressure level in the 1/3 octave band was 68 dB which is well below the recommended exposure limits.

7. Survey Instrumentation and Methodology

In this section some commonly used commercial instruments are described. Other equipment with appropriate specifications may perform just as well. In every case the calibration of the instrument must be verified at regular intervals.

The method of measurement is described in detail only for types of emissions whose level could be substantially above background levels.

There is no standard to the distance at which the measurements are taken, but Table 11 lists those commonly used.

Table 11 Commonly used distances from VDTs

Distance	Purpose
On the surface	To detect lowest emission intensities
5 cm from surface	To verify compliance with regulations
30 to 50 cm from surface	To measure exposure to operator

7.1 Measurement of electrostatic field

The Monroe Model 255 Electrostatic Field* meter can be used to measure the DC electrostatic charge on the VDT screen.

The measurement process is as follows:

1. Discharge your body by touching a grounded metal object.
2. Point the aperture at the end of the meter, toward a grounded surface or a large metallic object (e.g. file cabinet) and set the ZERO of the instrument.
3. Position the instrument so that the aperture faces the center of the VDT screen at a distance of *one* inch (2.54 cm) and read the display. The separation is measured from the front surface of the metal plate of the meter.

*Manufactured by Monroe Electronics, Inc., 100 Housel Ave, Lyndonville NY 14098, Tel (716) 765-2254. Distributed in Canada by: Repron Scientific Instruments, 206 Parkhurst Blvd, Toronto, Ontario, M4G 2G3. Tel (416) 425-5170

Measurement of electrostatic field *continued*

4. Since the displayed value is in kV/inch, and the measurement is done at a one inch distance from the screen, the instrument reading shows the potential of the screen in kilovolts.

5. Repeat 1. to 3. for additional measurements.

7.2 Measurement of ELF and VLF magnetic fields

The instrumentation used to measure ELF and VLF magnetic fields consists of the EMCO 6640 MFIM (Magnetic Field Intensity Meter) and the Model 3201 Ferrite Sensor Rod,* designed for measurement of magnetic fields over the frequency range of 0.1 Hz to 50 kHz.

The following is a summary of the procedures that should be followed for proper operation, as taken from the owner's manual:

Battery pack checkout

1. Place BATT POWER switch to the ON position.
2. Rotate the TEST SELECTOR switch to the -12 position. The TEST METER should indicate in the blue region (between -50 to -40).
3. Rotate the TEST SELECTOR switch to the +12 position. The TEST METER should indicate in the red region (between 40 to 50).

Pre-operation procedure

1. Connect the sensor to the 6640 and align the long axis of the sensor EAST-WEST
2. Turn the BATT POWER switch to the ON position
3. Set the SERVO switch to the FAST position.
4. Set the GAIN switch to 20 dB.
5. Set the TEST SELECTOR switch to the SERVO position.
6. Momentarily depress the AUTO lock pushbutton and release.
7. The TEST METER should read approximately (-38 to -10) midscale in yellow region for an EAST-WEST orientation.
8. Set the TEST SELECTOR switch to the AMPL position. The TEST METER should indicate in the narrow yellow region (10 to 20). The TEST SELECTOR switch should be in the AMPL position while the 6640 is in use. If the servo control is lost during a measurement procedure, the TEST METER will indicate in the midscale brown region (-10 to 10).

NOTE: If the servo control is lost, the AUTO LOCK pushbutton can be depressed and released to relock the servo.

*Manufactured and Distributed by the Electro-Mechanics Co., P. O. Box 1546, Austin, Texas, 78767. Tel (512) 835-4684. (No distributor in Canada).

Measuring procedure

1. Set the sensor probe onto the non-ferromagnetic tripod mount.
2. Connect the 25 ft (7.6 m) cable to the multiple pin connector on the end of the sensor and to the chassis connector marked SENSOR.
3. Connect the RMS voltmeter to the 6640 chassis connector marked ANALOG OUTPUT.
4. Set the SERVO switch to the FAST position.
5. Set the TEST SELECTOR switch to the AMPL position.
6. Turn the BATT POWER switch to the ON position.
7. Set the GAIN switch such that the voltage reading on the RMS voltmeter is 1V or less.
8. Use the calibration table (Table 12) to convert the exact voltage reading on the RMS voltmeter to the corresponding magnetic field intensity. Every 0.707 V measured corresponds to the magnetic field strength in the table for the particular gain switch setting.

Table 12 Field intensity at sensor to produce 0 dB reading

Gais Switch Setting (dB)	Model 3201 Probe (A/m)	Model 3202 Probe (A/m)
0	0.796	79.6
10	0.252	25.2
20	7.96×10^{-2}	7.96
30	2.52×10^{-2}	2.52
40	7.96×10^{-3}	0.796
50	2.52×10^{-3}	0.252
60	7.96×10^{-4}	7.96×10^{-2}

Note: 0.707 Vrms corresponds to 0 dB

7.3 Measurement of VLF electric field

VDTs may emit very low frequency (mostly the fundamental frequency, 15.75 kHz) electromagnetic radiation. The EFS-1 Electric Field Sensor* can be used to measure the effective (or rms = root-mean-square) VLF pulsed electric field around video display terminals. To measure the peak value of pulsed fields, the Model EFS-2 from the same manufacturer could be used. Both instruments are used in conjunction with three antennae. Performance specifications for these antennae are given in Table 13.

*Manufactured by Instruments for Industry, 151 Toledo St, Farmingdale, NY, 11735. Tel (516) 694-1414. Canadian distributor is Multilek Inc., 107 Colonnade Road, Ottawa, Ontario, K2E 7M3. Tel (613) 226-2635.

Table 13 Ranges of electric field measurement

Antenna	Scale Selection	Useful Range
Longest (12.7 cm)	LO	1 to 3 V/m
Longest	HI	3 to 10 V/m
Medium (2.54 cm)	LO	10 to 30 V/m
Medium	HI	30 to 100 V/m
Shortest (0.95 cm)	HI	100 to 300 V/m

The measurement process is as follows:

1. Turn the power switch to the "ON" position. Allow approximately 3-5 minutes for stabilization of the unit.
2. Install the antenna firmly in the threaded terminal in the top of the EFS-1. The range switch should initially be set to the "HI" position. The selection of the antenna size and corresponding scale is made using Table 13.
3. Hold the meter by the black handle and take the measurements *with the antenna pointing toward the VDT.* The VLF measurement should be taken at specific distances ranging from 10 cm to 30 cm on all sides and the top of the terminal cabinet. Measurement positions should be recorded as the distance from the antenna tip to the cabinet.

7.4 UV, visible and IR measurements

UV, visible and IR radiation are often called optical radiation. The instruments used for measuring optical radiation are called radiometers. The exposure is measured in units of incident energy or power per unit area during a given time interval or the incident power per unit area. The radiometric units used for energy measurement are the following:

1. joules per square centimeter (J/cm^2)
2. millijoules per square centimeter (mJ/cm^2)
3. microjoules per square centimeter (uJ/cm^2)

For the assessment of exposure rates (incident energy per unit time) the power density of radiation is measured in milliwatts per square centimeter (mW/cm^2) or microwatts per square centimeter (uW/cm^2).

The exposure measured in joules/cm^2 can be converted into watts/cm^2 using the following equation:

$$\text{watts/cm}^2 = \frac{\text{joules /cm}}{\text{seconds}}$$

UV, visible and IR measurements *continued*

The effectiveness of optical radiation in causing biological damage is dependent on the frequency of radiation. For this reason measurements of the spectral distribution of energy is desirable for broadband optical sources. Sprectroradiometers are used for this purpose.

Instruments that have been commonly used for UV measurements around VDTs include the following:

1. EG&G Model 580/585 Spectroradiometer
2. NRPB (National Radiation Protection Bureau) Scanning Spectral Radiometer (SSR)
3. IL730 A (International Light) actinic radiometer
4. Photodyne model 66 XL radiometer with UV sensor model 450
5. United Detector Technology (UDT) Model 40A radiometer.

For the measurement of visible light, photometric units of lux, lumen, and footcandle are used. The conversion factors between these units are as follows:

1 lux = 1 lumen per square meter

1 footcandle = 1 lumen per square foot
= 10.76 lumens per square meter
= 10.76 lux

The connection between photometric and radiometric units can be obtained from

1 lumen = 1.47 mW (at 555 nm)

The following instruments have been used to measure visible and near IR radiation from VDTs:

1. EG&G Type 550 Radiometer
2. UDT 40X Optometer
3. EG&G Model 580/585 Spectroradiometer
4. Photo Research Spectra Minispot-Photometer

Instruments from other manufacturers with a wide range of sensitivities and accuracies are available.

For the measurement of optical radiant power the screen should be completely filled with "M" characters and maximum brightness should be set. The distance from the screen should be 30-50 cm to duplicate the operator's position.

The exact procedure for the operation of the equipment is given in the users' manuals and must be carefully followed.

7.5 X-ray measurement

The X-ray exposure measurements are done using either scintillation or Geiger-Mueller (GM) detectors. These instruments measure exposure in either of the following units:

1. milliroentgens per hour (mR/h)
2. millirads per hour (mrads/h)
3. millirems per hour (mrem/h)

The basic requirements of the instrument are that it should be able to detect extremely low energy (a few kiloelectron volts) X-rays and it must be highly sensitive as the exposure levels of interest are extremely low. The response of the instrument should not vary with energy level. Also the meter should not be sensitive to the presence of radiofrequency radiation.

Instruments used for this purpose are the following:

1. Victoreen 440 RFC with GM probe (most commonly used)
2. Victoreen Model 444 GM probe and meter
3. TLD (Thermoluminiscent dosimeter)
4. Berthold LB 1200 GM Instrument
5. Eberline-E 140/HP 260
6. Ludlum Model 2200 with HP-210 GM Probe

In laboratory studies gamma spectroscopic instruments have been used to obtain spectral analysis of VDT X-rays.

7.6 Ultrasound measurement

Ultrasound measurements reported by the Bureau of Radiological Health (BRH) were undertaken by using Bruel and Kjaer instruments. The set-up consisted of the following:

1. Model 4133 Microphone (1/2 inch)
2. Model 2209 Sound level meter
3. Model 1616 One third octave filter set
4. Model 4220 Calibration pistonphone.

Similar instruments are available from other manufacturers of acoustic equipment.

8. Presentation of results and reports

A study involving an organization of reasonable size will generate voluminous data. In the final report only a condensed summary of these data are presented. However, the process of summarization should be such that no information is lost. For the particular case of VDTs the measured EM fields may show a considerable variation between different makes and models. For a given model, the variation may not be too large so that the measurements can

Presentation of results and reports *continued*

be presented as a range of measured values and one measure of central tendency (mean, mode or median or geometric mean). The conditions of measurement, types of instruments, sampling time and accuracy must be included in the report. Possible relationship between the age and physical state of the equipment and the level of emission must be examined.

8.1 Interpretation

The main objective of the survey is to determine whether or not a given population is exposed to a level which could be hazardous or injurious to health. The following facts must be critically examined before drawing conclusions:

1. Type of exposure
2. Average daily exposure
3. Highest exposure rate
4. Duration of exposure (length of employment)
5. Scientific data on dose-response relationship

In many cases no data on consequences of human exposure are available. Customarily, in such cases animal data are used for dose-effect relations. This fact must be clearly mentioned. In absence of any data on biological effects a common conservative approach is to keep the exposure as low as reasonably achievable (ALARA principle).

8.2 Comparison with other studies

It is likely that similar studies are reported by other institutions which may have had prolonged measurements over larger populations. It is important to compare the results with such studies. Any discrepancies must be thoroughly investigated to determine the cause of difference. Unless all possible sources of instrumental, methodological and mathematical errors have been absolutely ruled out any claims for an "improved" or "new result" must not be made.

8.3 Comparison with standards

The agency responsible for setting standards generally recommends the procedure of comparison. In most cases the limit of exposure is given as a time weighted average daily exposure and a ceiling value for maximum rate of exposure. The regulating authority responsible for the workplace in question may have more stringent or relaxed regulations compared to some of the professional organizations such as ACGIH. It must be ensured that comparison is done with limits applicable to the organization in question.

In cases where no exposure limits exist but the exposure has been proven or suspected to be hazardous, the cause of concern should be supported by scientific data.

8.4 Making recommendations

The purpose of making recommendations is either to call for an improved working condition or else to continue to ensure existing healthy conditions.

In order to ensure continued existing healthy working conditions the need for periodic evaluation should be examinded.

9. Glossary

Absorber	Any material that absorbs or attenuates the intensity of radiation.
Absorption	The process by which the number of particles or photons entering matter is reduced or attenuated by interaction with the matter.
ACGIH	American Conference of Governmental Industrial Hygienists.
Acute Radiation Syndrome (ARS)	Radiation sickness whose symptoms develop within minutes to hours after whole body exposure to high radiation dose given over a very short period of time (a few seconds to several minutes).
ALARA	Acronym for "As Low as Reasonably Achievable," a basic concept of radiation protection that specifies that exposure be kept as far below regulation limits as feasible.
Amplitude	The maximum (peak) value of a quantity sinusoidally varying with time or space.
ANSI	American National Standards Institute.
Antenna	A means for radiating or receiving electromagnetic waves.
ARS	See Acute Radiation Syndrome
Attenuation	The process by which a beam of radiation is reduced in intensity when passing through material. It is the combination of absorption and scattering processes.
Audible noise	Mechanical waves that can be perceived by human ear. The frequency range of audible noise varies from person to person. The maximum range is 20Hz - 20 kHz.
Background radiation	The radiation in man's natural environment, (both ionizing and nonionizing) including cosmic rays and radiation from the naturally radioactive elements in earth, and inside the bodies of humans and animals, emissions from radio and television transmitters. The average individual exposure from background radiation in the ionizing radiation range is approximately 125 millirem per year in mid latitudes at sea level.
Bradycardia	Abnormally slow heart beat.
CRT (Cathode Ray Tube)	Evacuated glass tube which houses an electron gun on one end and a phosphor coated videoscreen on the other.
Cardiovascular Systems (Circulatory Systems)	The heart together with the two (circulatory systems) networks of blood vessels; the systemic circulation and the primary circulation.

Glossary
continued

Cataract	Opacity of the lens of the eye.
Central Nervous System (CNS)	The brain and the spinal cord. The CNS is responsible for the integration of all nervous activities.
Conductivity (electrical)	The measure of a material's (electrical) ability to carry an electric current.
Conductors	Substances that allow electric current to pass through them. Most metals are conductors.
Conjunctivitis (Pink Eye)	Inflamation of the mucous membrane that covers the front of the eye and lines the inside of the eyelids.
Continuous Wave (CW)	A waveform whose amplitude is constant in time as opposed to pulsed or modulated. The output power is constant and equal to the average power.
Counter	A general designation applied to radiation detection instruments or survey meters that detect and measure ionizing radiation. The signal that announces an ionization event is called a count. (See Geiger-Mueller counter).
Critical organ	The body organ receiving radiation dose that results in the greatest overall damage to the body.
Dose equivalent	The product of absorbed dose (rads) multiplied by a quality factor (QF).
Dose	A quantity (total or accumulated) of radiation energy received in time. The absorbed dose, given in rads, represents the energy absorbed from the radiation in a gram of any material. The biological dose, given in rem, is a measure of the biological damage to living tissue from the radiation exposure.
Dosimeter	A portable instrument for measuring and registering the total accumulated exposure to radiation.
ELF (Extremely Low Frequency)	The region of the electromagnetic spectrum in the frequency range of 30-300 Hz (wavelength range 10^4 - 10^3 km). According to American Industrial Hygiene Association the ELF range is between 0 to 3 kHz.
EPA	United States Environmental Protection Agency.

Glossary *continued*

Electromagnetic radiation	A traveling wave motion resulting from changing electric and magnetic fields. Familiar electromagnetic radiations range from X-rays (and gamma rays) through the ultraviolet, visible, and infrared regions, to microwaves and radiofrequency waves ending at ELF. All electromagnetic radiation can travel in a vacuum and in air (with the velocity of light).
Electron	An elementary particle with a unit negative charge and a mass 1/1837 that of the hydrogen atom.
Electron gun	Electronic device that produces a beam of electrons.
Electrostatic field	Electric field produced by a stationary charge whose magnitude does not vary with time. The magnitude of electric field is given in volts per meter (V/m).
Electric field	Field developed between two different charges. A region in which electrically charged bodies are subject to effective forces.
Electric field strength	The magnitude of the electric field in volts per meter (V/m).
Epidemiological study	Study of disease occurrence in a community during a specific time.
Exposure	The absorption of radiation. Acute exposure is generally accepted to be a large exposure received over a short period of time. Chronic exposure is low-level exposure received over a prolonged period of time.
Far-field region	The region of the radiation field from a source where there exists a uniform distribution of the electric field strength and magnetic field strength. In the far field, the inverse square law is valid.
Flux	The amount of radiation crossing unit area per unit time.
Flyback transformer	A transformer used to produce the high voltage for the CRT.
Foot candle	See lux. 1 foot candle = 10.76 lux.
Foot lambert	Measure of the reflected or transmitted brightness. 1 foot lambert = 1 lumen/square foot.
Frequency	Number of waves or cycles produced per second. The unit of frequency is a hertz (Hz) where 1000 Hz = 1 kHz (kilohertz) 1000 kHz = 1 MHz (megahertz) 1000 MHz = 1 GHz (gigahertz)

Glossary *continued*

Fundamental frequency	The lowest frequency component in the Fourier representation of a complex periodic signal.
Gamma ray (Gamma radiation)	High-energy, short wavelength electromagnetic radiation emitted from the atomic nucleus. Gamma rays are very penetrating and are best stopped or shielded against by dense materials, such as lead. Gamma rays are similar to X-rays, but are usually more energetic.
Geiger-Mueller counter	A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes. The number of pulses per second measures the intensity of radiation. It was named for Hans Geiger and W. Mueller who invented it in the 1920s. It is sometimes called G-M counter.
Gigahertz (GHz)	The unit of frequency equal to 1,000,000,000 Hertz.
Gray	A unit, in the international System of Units (SI), of absorbed dose which is equal to 1 joule per kilogram.
Hematological system	Blood and related organs.
Hertz (Hz)	Unit of frequency. One Hz equals 1 cycle per second.
Hyperthyroidism	Excessive activity of the thyroid gland.
Hypotension	Abnormally low blood pressure.
IRPA	International Radiation Protection Association.
Infrared Radiation (IR)	Electromagnetic waves with wavelength shorter than microwaves but longer than visible light. The primary effect of IR radiation on biologic tissue is thermal. IR is produced by heat sources.
Inverse square law	This law is said to be obeyed when the power density varies as inverse of the square of distance from the source of radiated power. At double the distance, the power density is one quarter.
Ion	An atom that has too many or too few electrons, causing it to be electrically charged.
Ionization	The process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions.
Ionizing radiation	Any radiation capable of displacing electrons from atoms or molecules with a single photon, thereby producing ions.

Glossary *continued*

Irradiation	Exposure to radiation.
Joule	SI unit of energy. 1 watt = 1 joule per second.
Kilohertz (kHz)	The unit of frequency equal to 1000 Hertz.
Kilovolt (kV)	The unit of electrical potential equal to 1000 volts.
Lumen	Unit of measure of light output from a source. 1 lumen = 0.078 candela.
Lux	Unit of measure of incident light on a surface. 1 lux = 1 lumen/square meter = 0.0926 foot candle.
Magnetic field	Field developed around a moving charged particle. An example is a magnetic field generated by the flow of electrical current through a wire. The magnetic field is measured in units of amperes per meter (A/m).
Mean	Arithmetic average.
Median	If all the measured values are arranged in a row of increasing or decreasing order then the number that corresponds to the centre of the row is the median.
Megahertz (MHz)	The unit of frequency equal to 1,000,000 Hz.
Microwave region	The region of the electromagnetic spectrum encompassing the frequency range 300 MHz to 300 GHz.
Mode	a) Most frequently encountered values in a set of data. b) a particular form of a variety of possiblities.
Molecule	A group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties.
Monitoring	Periodic or continuous determination of the amount of radiation or contamination present in an occupied region, as a safety measure, for purposes of health protection.
Nausea	The feeling that one is about to vomit, as experienced in seasickness.
Near-field region	The radiation field in the vicinity of the source in which the field distribution is critically dependent on the direction and distance from the antenna. The inverse square law is not obeyed in this region and a simple relation does not exist between the electric field strength and the magnetic field strength.

Glossary *continued*

Nonionizing radiation	The part of the electromagnetic spectrum with frequencies below about 10^{15} Hz. While traversing matter these rays cannot produce ion pairs.
Non-thermal (or athermal) effects	Health effects of nonionizing radiation exposure which can occur even in the absence of any tissue temperature rise. Some neurologic, physiologic and behavioural effects fall in this category.
Occupational exposure	Exposure received by an employee as a result of performing a job related to his employment.
Octave band filter	A filter used in conjunction with a sound level meter to measure the distribution of noise level in different octave bands.
One third octave band filter	A set of filters used to measure the sound intensity in narrower bandwidths. Each octave band is divided into three one third octave bands.
Peripheral nervous system	All parts of the nervous system lying outside the brain and the spinal cord.
Photokeratitis	Inflammation of the cornea.
Photometer	An instrument used to measure intensity of light.
Photon	The smallest quantum of energy emitted in the form of electromagnetic radiation.
Photosensitizing agents	Chemicals and drugs that enhance the biological effectiveness of radiation.
Pistonphone	A calibrated single tone noise generator used to check the calibration of sound level meters.
Pocket dosimeter	A small detection instrument that gives personal radiation exposure directly.
Power density	Incident electromagnetic radiation per unit area of exposed surface measured in watts per square meter (W/m^2) or milliwatts per square centimeter (mW/cm^2).
Pulsed EM radiation	Short duration bursts of electromagnetic radiation.
Quality factor (QF)	A multiplicative factor used to calculate dose in rem (or Sv) from the absorbed radiation energy dose in rads or gray (rem = rad x QF and Sv = gray x QF). For X-rays QF = 1.
Quantum	Discrete unit quantity of energy.

Glossary *continued*

Rad	Acronym for radiation absorbed dose. The basic unit of absorbed dose of radiation. A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing material.
Radiated power	Power emitted by a source in watts or joules per second.
Radiation area	Any accessible area in which the level of radiation is such that a major portion of an individual's body could receive in any one hour a dose in excess of 5 millirem, or in any five consecutive days a dose in excess of 100 millirem.
Radiation shielding	Reduction of radiation exposure by interposing an absorbing material between the source and a person's work area or radiation-sensitive device.
Radiofrequency region	The region of the electromagnetic spectrum between 300 kHz and 300 MHz.
Radiological survey	Measurements or estimates of the levels of radiation that may be produced, and a sufficient knowledge of processes affecting these sources to predict hazards.
Radiometer	An instrument used to measure the radiated power or energy.
Radiosensitivity	The relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation.
Raster scan technique	Technique of producing images and characters on the CRT screen by scanning the entire screen by an electron beam along a fixed number of lines (262 for VDTs and 525 for TV sets). The brightness of different regions is controlled by varying the electron beam intensity.
Rem	Acronym of roentgen equivalent man. The unit of dose of any ionizing radiation. (1 rem = 10 mSv)
Roentgen (R)	A unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, a German scientist who discovered X-rays in 1895.
SAR	Specific absorption rate. The rate at which energy is absorbed in the body in units of watt per kilogram (W/kg).
Scattered radiation	Radiation that, during its passage through a substance, changes direction.

Glossary
continued

Scintillation detector or counter	The combination of phosphor, photomultiplier tube, and associated electronic circuits for counting light emission produced in the phosphor by ionizing radiation.
Serotonin	A compound present in blood serum.
Sievert (Sv)	A unit, in the International System of Units (SI), of dose equivalent. 1 Sv = 100 rem.
Somatic effects of radiation	Effects of radiation limited to the exposed individual, as distinguished from genetic effects, which may also affect subsequent unexposed generations.
Sound level meter	Instrument used to measure the intensity of noise.
Spectroradiometer	A radiometer capable of measuring the distribution of radiated power (or energy) in different wavelengths.
Survey meter	Any portable radiation detection instrument especially adapted for inspecting an area to establish exposure.
Thermal effects	Health effects resulting from tissue temperature rise due to electromagnetic radiation exposure.
Threshold Limit Value (TLV)	A concentration (in air) of a material, or a level of noise or radiation, to which most workers can be exposed daily without adverse effect. Threshold limit values, established by the American Conference of Governmental Industrial Hygienists, are time-weighted values for a 7 or 8-hour workday and 40-hour workweek. In most cases exposures exceeding the limit are permissible provided there are equivalent compensatory exposures below the limit during the workday (or in some cases the week).
Tinnitus	Sensation of a buzzing or ringing noise in the ear.
Ultrasound	Mechanical waves whose frequencies are higher than audible sound (typically above 16 kHz).
Ultraviolet (UV)	Electromagnetic radiation with wavelength shorter than visible light but longer than X-rays. The UV-region is further divided into three parts. UV-A is the region that has wavelength closer to that of visible light and UV-C has closer to X-rays. The middle part is UV-B which is responsible for effects on the eye and skin.
VLF (Very Low Frequency) region	The region of the electromagnetic spectrum in the frequency range 3-30 kHz (wavelength range 100-10 km).
Wavelength	The distance traversed by the wave during the time it completes one oscillation (period of oscillation). wavelength = speed/frequency

Glossary
continued

Weighting factor	Relative weights used to determine risk from the irradiation of individual organs by ionizing radiation.
Whole-body exposure	An exposure of the body to radiation, in which the entire body rather than an isolated part is irradiated.
X-rays	Penetrating electromagnetic radiation having less energy than gamma rays but greater energy than ultraviolet rays.
Yoke	Iron core around which a coil is wound to make electromagnets, transformers and chokes.